Invasive Species Early Detection Monitoring Protocol for Klamath Network Parks

Standard Operating Procedure (SOP) #10: Reporting and Analyses of Data

Version 1.00 (February 2010)

Revision History Log:

Previous Version	Revision Date	Author	Changes Made	Reason for Change	New Version

This SOP provides details of the reporting and analysis elements of the Invasive Species Monitoring Protocol. The reporting and analysis of data are tailored to the monitoring objectives for the invasive species protocol:

1. Detect populations of selected invasive plants by sampling along roads, trails, and powerline corridors, and in campgrounds, where introduction is most likely.
2. Provide the information to park management on a timely basis to allow effective management responses.
3. Develop and maintain a list of priority invasive plant species with greatest potential for spread and impact to park resources for monitoring in each park.
4. Adapt spatial sampling as knowledge improves through monitoring.
5. Use monitoring data collected from this protocol and the vegetation protocol to estimate possible trends and develop and refine models of invasive species habitat requirements and of the most susceptible habitats (both along roads and trails and not).

In order to accomplish these objectives, data and results will be reported and analyzed in reports prepared at varying frequencies and levels of detail (Table 1). Reports will be stored in NatureBib, posted on the Klamath Network Internet and Intranet web sites, and uploaded to Southern Oregon University's Bioregional electronic archive collection. Reports will also be sent to the Technical Advisory Committee and to park staff involved in invasive species management. In addition, reports and the database will be used to update NPSpecies. Reports will be formatted using the Natural Resource Technical Report template found at NPS Natural Resource Publications.

Table 1. Overview of general reporting tools with purpose/objectives and reporting year.

Report	Year	Purpose/Objective				
		1. Detect populations and trends of selected invasive plants.	2. Provide the information to park management on a timely basis.	3. Develop and maintain a list of priority invasive plant species with greatest potential for spread.	4. Adapt spatial sampling as knowledge improves through monitoring..	5. Use monitoring data collected from this protocol and the vegetation protocol to develop and refine models.
Park Briefing	All sampling years	X	X			
Biennial Reports	All Non-sampling years	X	X		X	
A&S Report 1: Management Effectiveness	Year 6		X	X		
A&S Report 2: Spatial Models	Year 12	X	X		X	
A&S Report 3: Temporal Dynamics	Year 18	X		X	X	X

Briefings

To accomplish the first monitoring objective, parks will be briefed on the invasive species early detection findings expeditiously in three ways. First, field crews will meet with park resource staff to present findings during or upon completing their seasonal field work. The purpose of these meetings will be to convey the most urgent findings verbally, so that park managers can schedule immediate treatments if appropriate and feasible. In some cases, the crew may use cell phones to contact park managers from a field location. Second, a one page briefing paper will be developed after the field season (by December 1st). This paper is not meant to convey all the findings and efforts for the year but to act as an interest document that summarizes the most urgent and relevant information to managers, Network-wide, to facilitate rapid response. Third, all occurrences of priority species documented will be provided as a GIS layers to be delivered no later than December 1st of the year of a survey.

Biennial Reports

More detailed and formal reports will be prepared in years following the field seasons. These reports will focus on the status of invasives, the time spent surveying, and kilometers covered presented in tabular data as shown in Appendix B. To address monitoring objective one, the reports will document all findings related to goals of early detection and include management recommendations to be implemented during alternate years. Biennial reports will be prepared and distributed by May 1st of the year following monitoring.

Biennial reports will include occurrences of priority species by road, trail, campground, and powerline in map and tabular form. A separate map will be constructed for each priority invasive at each park (Figure 1). Maps are intended to assist resource managers in designing control strategies for invasive species. New invasions, previous invasions, concentrations of invasions, and invasion-free areas will be highlighted on these maps. Summary statistics will also be provided in these reports. Summary statistics will include invasive species frequency by park. Frequency is defined as the number of segments in which an invasive occurs. Frequency will be calculated in the following manner:

Equation 1: Frequency of an invasive species (%) =

$$\frac{\Sigma \textit{ segments occupied by species } *100}{\Sigma \textit{ units sampled}}$$

Correlations between invasive species and plot level variables, as shown in Table 2, will also be provided. Pearson Product Moment correlations will be calculated if data have a normal distribution or can be transformed to have one. If cover data cannot be normalized following transformation, then non-parametric Spearman Rank Correlation coefficients will be calculated. The correlations in Table 2 illustrate a fairly strong negative relationship between the invasive, St. John’s wort, or Klamath weed (*Hypericum perforatum*), percent cover of litter, and low light conditions.

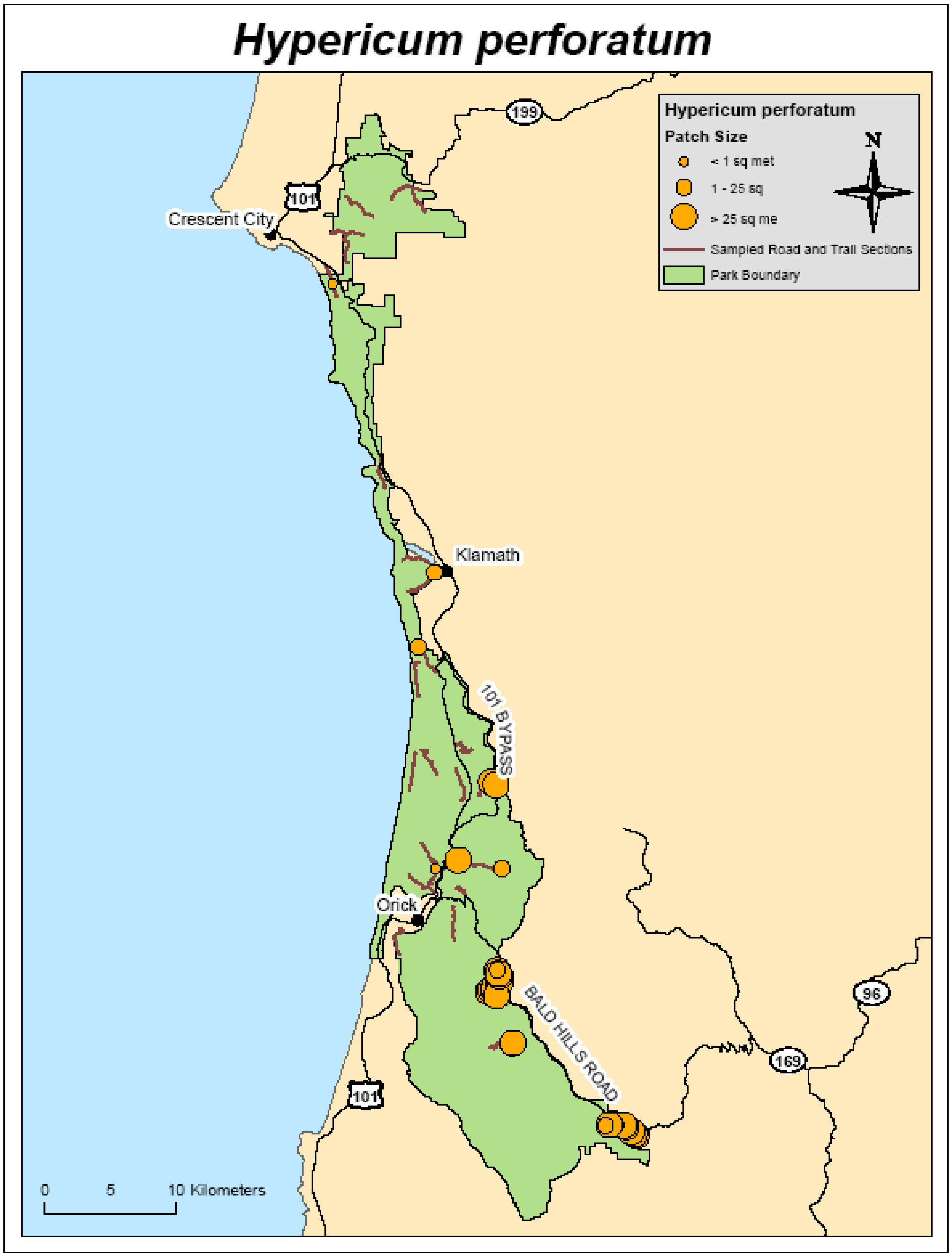

Figure 1. Map showing 2007 infestation location and size for Klamath weed (*Hypericum perforatum*) at Redwood National Park.

Table 2. Spearman Rank correlation coefficients between plot variables and Klamath weed (*Hypericum perforatum)*. Data analyzed are from the pilot study (Lundgren et al 2008, Appendix A).

	***Hypericum* cover**	**Slope**	**Aspect**	**Ever-green cover**	**Decid-uous cover**	**Herb-aceous cover**	**Shrub cover**	**Woody debris**	**Litter**	**Bare ground**	**Light Index**	**Disturbance**
***Hypericum* cover**	1.000											
Slope	-0.171	1.000										
Aspect	-0.042	0.218	1.000									
Evergreen cover	-0.251	0.169	0.075	1.000								
Deciduous cover	-0.074	0.036	0.051	-0.251	1.000							
Herb cover	0.106	0.119	0.074	-0.031	-0.275	1.000						
Shrub cover	-0.111	-0.051	-0.134	-0.095	0.258	-0.387	1.000					
Woody debris	-0.389	0.265	-0.009	0.527	-0.015	-0.030	0.138	1.000				
Litter	-0.459	0.201	0.044	0.610	0.079	-0.069	0.185	0.590	1.000			
Bare ground	0.215	-0.072	-0.053	-0.427	-0.018	-0.018	-0.250	-0.403	-0.796	1.000		
Light index	-0.363	0.200	-0.028	0.538	0.196	-0.278	0.333	0.511	0.589	-0.417	1.000	
Disturbance	0.242	-0.027	0.082	-0.363	0.133	0.067	-0.178	-0.346	-0.477	0.587	-0.378	1.000

An additional analysis that may be done with continuous multivariate normal data is to construct a directed acyclic graph (DAG) or chain graph that displays the dependence relationships among the variables (Shipley 2000). Although a DAG or chain graph is a "causal model," one can interpret the results in terms of associations among variables in the context of observational data. Such an exploratory graph is an additional tool to a correlation matrix because it displays the partial correlations in addition to the first order correlations.

The Tetrad software, available as a free download from http://www.phil.cmu.edu/projects/tetrad/, can be used to generate a directed acyclic graph based on the correlation structure between the continuous habitat variables measured at each plot. Currently, the available technology is only developed for all continuous or all categorical variables. An example is provided in Figure 2, displaying the relationships among the measured habitat variables. Because the cover of the invasive species, Klamath weed (*Hypericum perforatum*) was only measured at three levels in the pilot study, it was not possible to include this parameter with the continuous variables. However, future monitoring will measure cover of invasives on a continuous scale and it can be included in an analysis such as this.

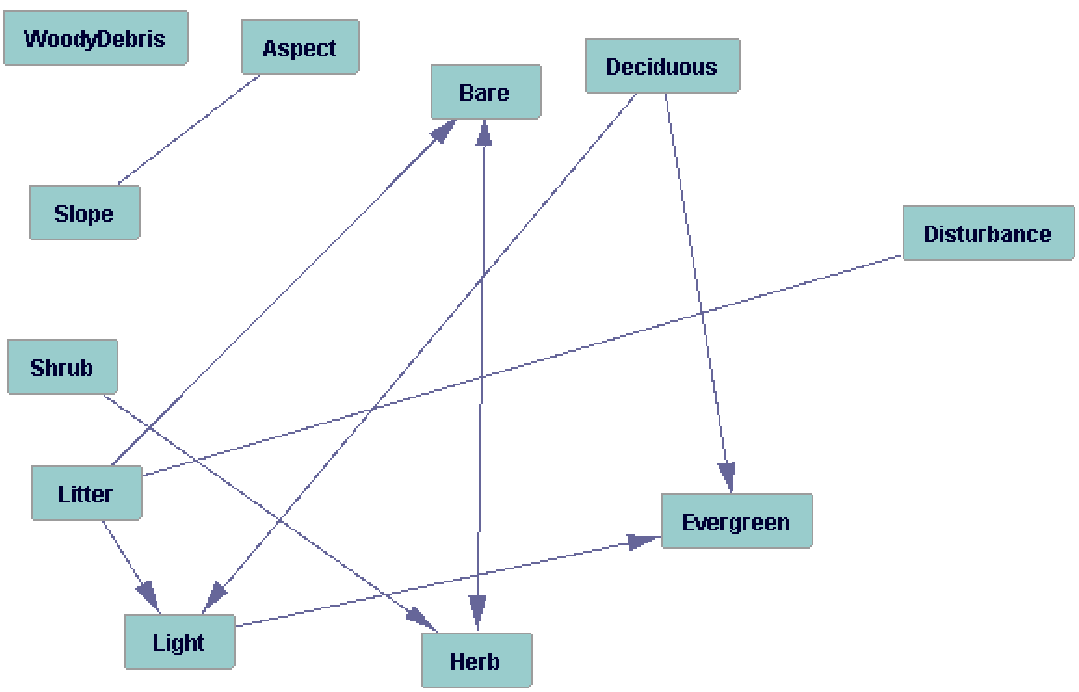

Figure 2. Chain graph for Klamath weed (*Hypericum perforatum*) habitat variables only. A directed arrow suggests a "causal" relationship between the variables.

Figure 2 is a chain graph that shows directed arrows (→) and bi-directed arrows (←→). A directed arrow suggests a "causal" relationship between the variables. For instance, the percent cover of deciduous trees influences the light index at a site. A bi-directed edge or a line without arrows suggested a correlation between variables. For example, as disturbance and litter are associated, notice in Table 1 that they have a negative correlation.

Figure 2 is a hypothetical example of a chain graph without any user input. The graph structure can also be restricted based on the known biology of the system. For example, if we know overstory structure would influence whether a light-demanding understory species may occur, we would only allow for edges in that direction. The edges in the graph can be estimated using Maximum likelihood or Bayesian estimation procedures. Ultimately, this analysis can allow managers to identify what environments are most susceptible to invasion.

Analysis and Synthesis Reports

Analysis and Synthesis Reports will be prepared every 6 years to address specific management and scientific objectives (Table 3). They will be prepared and distributed by June 1st, every sixth year. Specific Analysis and Synthesis Reports, hereafter A&S Reports, will address specific objectives and topics, ranging from management effectiveness to the autecology of invasive species in park landscapes. The scope and delivery schedule for A&S Reports is intended to provide specific topical information; not all questions of interest can be addressed in each report. We have assigned initial topics for the first three A&S Reports (Table 1).

A&S Report 1-Invasive Species Management Effectiveness

This report will evaluate the overall effectiveness of the protocol in providing useful, accurate, and timely information for the parks of the Klamath Network. The report will include maps illustrating cumulative sites visited over three sampling seasons for each park, locations and sizes of infestations encountered, and preliminary models of encounter probabilities for selected species.

The Program Lead will work with Park Contacts to coordinate and convene an assessment meeting in fall or winter following the third sampling season. At the meeting, I&M staff will present general scientific findings from the program (the first section of the report) and engage the park staff in a discussion about the monitoring approach and its effectiveness in assisting park management. In addition, I&M staff will request treatment data from the parks to help in the visualization of possible linkages between treatment actions and species presence over the initial period. Specific topics addressed at the meeting will include 1) a reevaluation of the method for invasive species selection and prioritization; 2) efficiency and comprehensiveness of sampling for providing management data supporting particular actions; 3) effectiveness of briefings, GIS data layer summaries, and biennial reports for supporting management actions; and 4) evaluation and description of linkages between management actions and species abundances, if applicable. The second section of the report will summarize the findings and recommendations arising from the invasive species management meeting.

A&S Report 2-Spatial Models of Invasive Species in the Klamath Network

This report will focus on the development of quantitative habitat models in the parks of the Klamath Network using spatial and nonspatial modeling (e.g., Guisan and Zimmermann 2000, Lawler and Edwards 2002, Edwards et al. 2007). The data available for use in model development will include six sampling cycles of invasive species monitoring data and three sampling cycles of vegetation monitoring data. As this report may require specialized programming and analysis techniques, it is possible that the Network will choose to contract this report out to scientists with the USGS or academia. However, improvements in spatial modeling features in standard mapping software (e.g., model builder in ArcGIS) may allow this report to be prepared in-house, if funding is limiting.

For example, we summarize a modeling approach in Appendix B that used general linear modeling to produce interpolated maps from point sampling data of the mean response variables and associated standard error terms from our pilot data. Landscape scale variables were generated in ArcGIS 9 and used to create species-environment matrices for each the species being modeled. These matrices were imported in the statistical package "R," where species-environment relationships were explored and modeled. The resultant models were mapped using the ArcGIS raster calculator and a testing dataset was used for model validation in R. Appendix B provides step-by-step directions, R scripts for modeling, and examples of each step of the process using data from the pilot study. Maps of the modeled surfaces are produced with the step-by-step instructions and procedures for model testing and validation are provided. Pertinent modeling literature is also reviewed.

Models will aim to predict beyond the current known range of invasive species to new areas in the parks that may be susceptible to invasion, facilitated by use of data from the vegetation monitoring protocol. Because all samples, even with the vegetation monitoring data, will be based on sampling within 1 km of roads and trails, the predictions cannot presume the same probability of invasion occurs in environments beyond this distance. However, as explained in the Klamath Network's monitoring plan (Sarr et al. 2007), the environments within a km of roads and trails are very representative of those park-wide. The biggest difference is the presence of the roads and trails. Examples of the modeling output using data from the pilot study are shown in Figures 2-3. Note that different variables were included in the final models for each species.

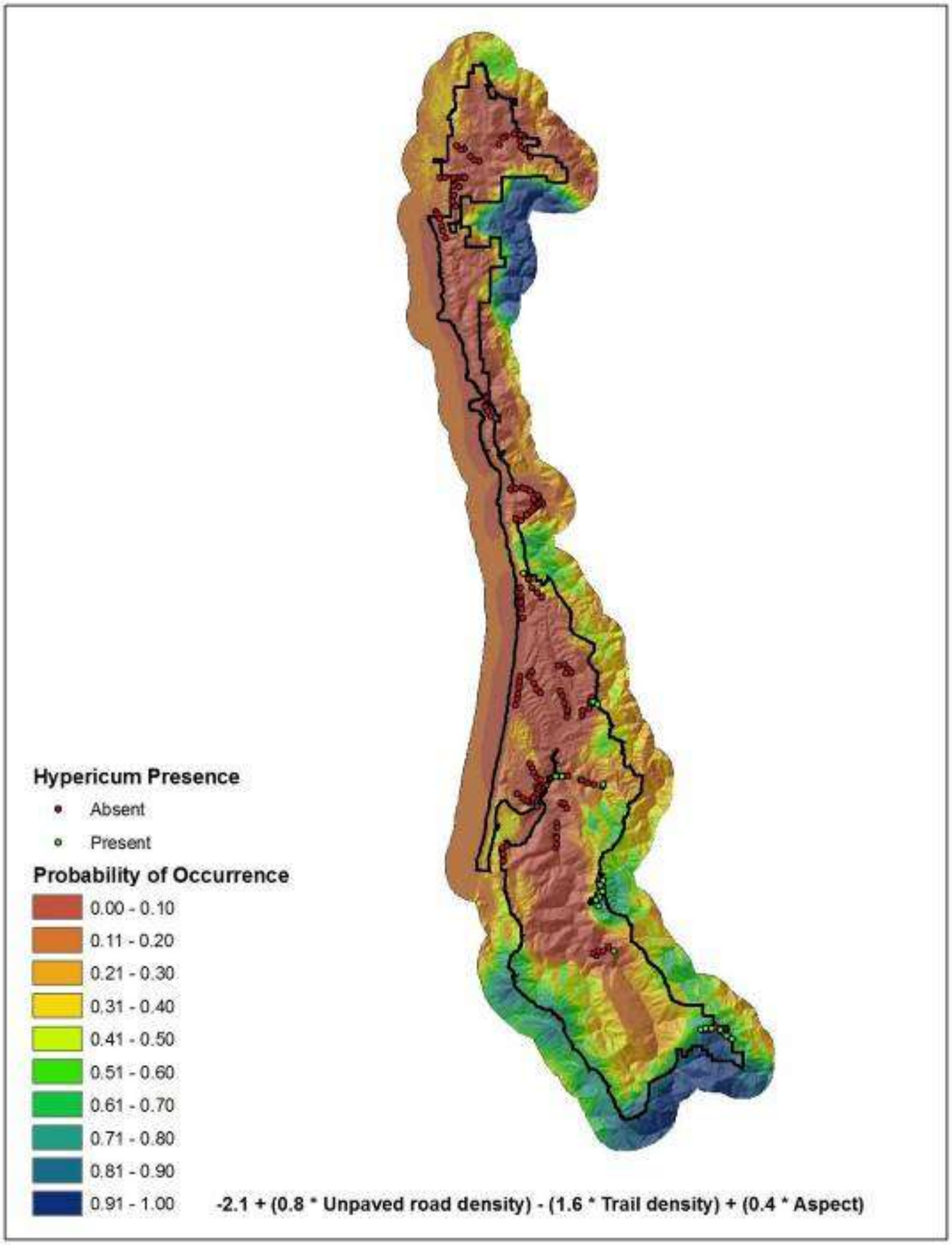

Figure 2. Interpolated surface showing the probability of occurrence of Klamath weed (*Hypericum perforatum*) at Redwood National Park.

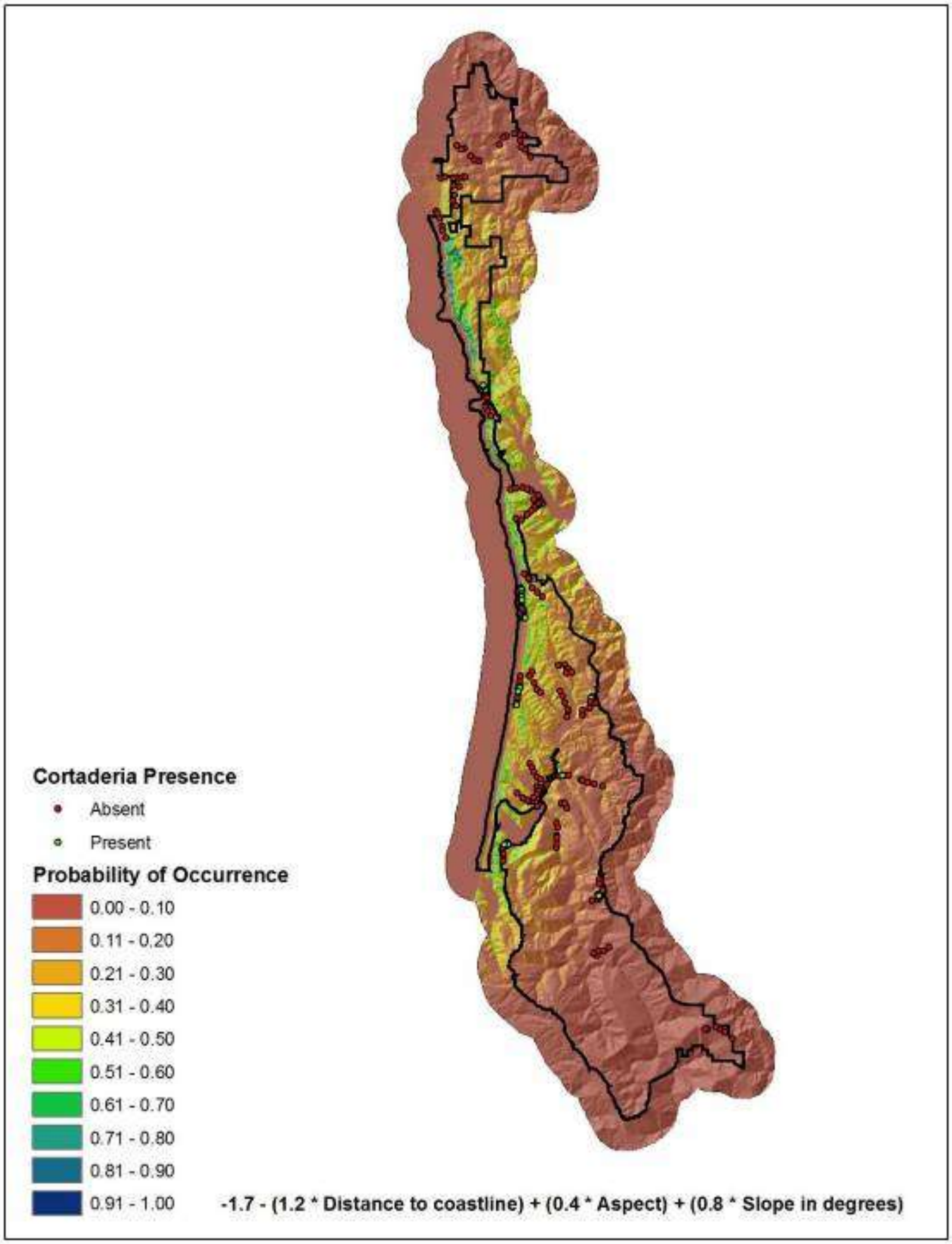

Figure 3. Interpolated surface showing the probability of occurrence of pampas grass (*Cortaderia jubata*) at Redwood National Park.

A&S Report 3-Temporal Dynamics of Invasive Species in the Klamath Parks

This report will use data from nine sampling cycles of invasive species and five sampling cycles of vegetation monitoring to evaluate the temporal dynamics of invasive plant species in the

Klamath parks. Trend detection will be a lower priority for this monitoring protocol than in other Network monitoring protocols because we expect that monitoring data will support invasive species control, removal, and possible eradication. Nonetheless, a better understanding of the temporal dynamics of invasion is very important both for management and for our program's contributions to invasive species science.

Where appropriate, estimates of invasive species trends will also be addressed using standard methods for temporal trend detections. Data from the vegetation protocol will be instrumental for this objective. Four calculations compare changes in individual segments sampled over time by species: 1) change in density for each segment between years (Equation 2), 2) changes in area occupied in segments sampled between years (Equation 3), overlap in segment occupancy (Equation 4), and 4) persistence over all sampling periods (Equation 5). Segments may not be resampled until the third or fourth sampling season in some cases, so it will be necessary to perform more than one different analysis for each type of trend and then evaluate the averages. Mean values for road, trail, and powerline segments in a park or across the Network can also be calculated for equations 2-3, allowing for confidence intervals and statistical comparisons over different windows of time. These calculations will be presented in summary tables.

Equation 2. Changes in density class in co-sampled segments =
(*density in segments during time 2 – density class in same segments during time 1*)

Equation 3. Changes in area occupied in co-sampled segments =
$$\Sigma \textit{ infestation sizes } (m^2) \textit{ in segments during time2 } - \Sigma \textit{ infestation sizes } (m^2) \textit{ in same segments during time 1}$$

Equation 4. Overlap in segment occupancy =
$$\frac{\textit{number of segments occupied in Time 1 and Time 2}}{\textit{the lower of the number of same segments occupied in Time 1 or Time 2}}$$

Equation 5. Persistence = *Number of years in which a segment was occupied*

Geostatistical-temporal modeling (Kyriakidis and Journel 1999) and general linear models (Manley 2001) will also be used to identify whether or not the spatial patterns are changing over time. After several sampling cycles, trends will be tested statistically using repeated measures ANOVA. Interpretation of trends will require assessment by park managers of any park management actions that may have affected invasive species abundance in areas surveyed.

The association between species establishment and persistence in specific landscape or stand conditions has been a major goal in plant ecology, and has important implications for the composition and structure of the ecosystem (Bormann and Likens 1977, Oliver and Larson 1996). The "niche" of a given invasive species in a park landscape is usually poorly known, but is essential information for long-term resource protection. Spatial models will likely provide important insights into where species can invade and why, but temporal information is also very desirable, particularly where there is a linkage with management.

Many management activities, such as prescribed fire, may create opportunities for some species and limit others. Analysis and synthesis of temporal dynamics in invasive species will require connecting data from this protocol with supplementary data from the vegetation protocol to detect meaningful changes in invasive species abundance and distribution over time. At a minimum, analyses of nontrend dynamics will include outlier and control chart analyses (Gilbert 1987, Morrison 2008) to document irruptive events relative to the baseline developed over several sampling cycles. More sophisticated analyses will explore linkages among potential drivers, such as park management history; wildfire and other natural disturbances; climatic variability; and invasive species abundance, distribution, and diversity. Such a synthesis will involve opportunistic analyses of pre-disturbance and post-disturbance data, as well as development of temporal correlations between climatic or other fluctuations and species spread.

Because many management activities may affect invasive species dynamics, a major goal of a collaborative early detection and rapid response program for the Network will be development of standardized means to record and summarize management data over time. Such an effort will require considerable input and support from park managers and is not part of the protocol at this time. However, the data collected under this protocol will be well suited to allow such analyses when matching park support materializes. In the interim, insights into ecologically relevant landscape changes (e.g., landcover transitions from forest to grassland) may be available from the Klamath Network Landcover Protocol currently under development.

<u>Vector and Pathway Analyses</u>. Many new exotic species tend to be introduced into communities via similar vectors or along the same pathways as previous introductions (Ruiz and Carlton 2003). As a simple descriptive analysis, we will develop GIS maps of invasives species location and abundance over time. These can be converted to PNG images and converted to space-time animations using software such as the Geographic Resources Analysis Support System (GRASS) and uploaded to Windows Movie Maker to create Windows Media Video (WMV) files. Such movies can be developed for each species and park to illustrate both the locations of detection, and subsequent movement through the park. We expect that these sorts of analyses will become much easier over time as desktop imaging software improves. Panels of invasion time series will be included in the report, with movies posted to the I&M web site. Our data will also allow much more sophisticated modeling analyses to be conducted by USGS or university partners, as needed.

These briefing, Biennial reports, and A&S Reports described here are intended to be feasibly completed by the I&M staff, with assistance from park staff, and occasional academic partners within the limits of available funding and staff time. We anticipate that meaningful studies of will also be conducted by outside scientists describing many aspects of invasive species ecology and biology in the parks. These will be accomplished through supplemental funding or staffing.

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